Signalling System 7

The mystery of instant worldwide telephony is exposed.

JEFF HEWETT

MOST OF US DON'T STOP TO CONSIDER the "magic" of instant worldwide communications that takes place when we pick up our phones. Whether we want to make a call to a phone in the house next door or on another continent, we just expect the magic to happen. When your call travels even a short distance, it becomes part of traffic on a network that's well known to only a relatively small number of people. The network is called Signaling System 7, or SS7. Over the past five to ten years, telephone operating companies have been upgrading their networks to use this standard communications protocol, providing them with faster call setup times and the ability to expand their service offerings.

You don't hear much about the SS7 communications network until it fails—but then it makes the headlines. Two incidents on the east coast a few years ago grabbed national news attention when large portions of the telephony network lost service due to SS7 outages. Staggering revenue loss was reported due to the loss of communications by businesses.

Electronics Now readers should be interested in understanding SS7 technology because communications is one of the fastest growing areas in the electronics arena today. Information is now a cornerstone of our society, and delivering that information readily from one point to another is of utmost importance. There is a proliferation of communications services ranging from caller ID to cellular service to ISDN and the forthcoming AIN or Advanced Intelligent Network. SS7 plays a major part in many of these services providing the means for transporting information between locations. So, let's take a look at what this alphabet-sounding technology does and how it works.

In-band vs. out-of-band

When a phone call is made, call-control information is sent to the local telephone office. The digits dialed are the main routing components that determine a call's destination. If the dialing is for a local call, the call may be connected from the same office from which the originating line terminates. Many times,

www.americanradiohistory.com

the telephone switch at the local office that services a phone line may have to route a call to another office connected by a trunk. Call-control signals such as the number dialed and the answer indication from the other end are information used for managing a call connection.

Using traditional signaling methods, the trunk between the two offices carries information down the same set of wires that the voice signal travels. This is called *in-band signaling* because the call-control signaling is sent down the same path as the voice signal. Signaling System 7 handles all these tasks on a separate facility known as a *signaling link*. The signaling link can handle the call-control information for many calls going on simultaneously. The actual voice path between the two offices is still over the trunks, while the call-control signaling is traveling on a separate communications channel. This is called *out-of-band* signaling. Figure 1 diagrams the in-band and out-of-band technique.

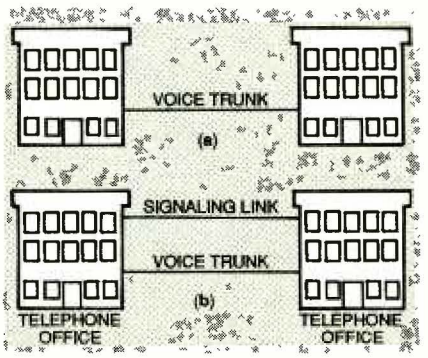

FIG. 1—SIMPLIFIED CONNECTIONS for In-Band (a) and Out-Of-Band (b) signaling between telephone offices.

SS7 is essentially a *packet switching network*. Signaling information is carried in data packets between the telephone offices in much the same manner as X.25 or other packet-switching protocols previously installed. This packet-switching network is overlaid on top of the existing telephony network, adding an entirely new dimension. This gives the telephony network a number of advantages over the traditional signaling system. The primary benefit is increased bandwidth for call signaling. The voice trunk is limited since its primary responsibility is to carry voice or data. SS7 provides additional bandwidth, a standardized protocol for sending information between different vendor equipment and increased data transmission speed.

Demand for network services

The greatest benefit for both the telephone operating companies and their subscribers is the increased capability to provide network services. Prior to using SS7, many telecommunications equipment vendors had proprietary means for sending feature-related signaling between offices. This prevented true networking of services. When Integrated Digital Services Network (ISDN) was introduced into the marketplace a few years ago, one complaint was its limited service across geographical locations. This created situations which came to be known as "ISDN islands." SS7 eliminates this problem by encapsulating the ISDN call information in packets and transporting them across the network, bridging the islands.

SS7 enables or enhances a number of services including:

- Enhanced 800 service
- Custom Local Area Signaling Services (CLASS)
- Advanced Intelligent Network Services (AIN)
- ISDN Connectivity
- Cellular Service

We will try to encapsulate a discussion on how SS7 works with each of above services by looking at just a few of them. Until recently, when you purchased 800 service, the number you were given actually belonged to the local company that was the service provider. FCC rulings in recent years have changed this scheme. Now with an enhanced form of 800 service, the 800 number can be retained by the subscriber even when he switches service providers. However, this means that the telephone company can no longer determine which service provider to route the call to just by the 800 number that's dialed. SS7 provides the capability to query a database to determine the service provider for routing the call to as well as other information associated with the call. Refer to Fig. 2.

Custom Local Area Signaling Services (CLASS) use SS7 capabilities to deliver services such as caller ID (identification), automatic redial, and call screening. Call screening allows the consumer to selectively accept or reject calls from selected numbers. The information for these services is transported between offices via SS7 packets.

The standards

The ability to provide information between phone offices without regard for which vendor's equipment is used requires global standards. Standards are developed at different levels by different organizations. Global SS7 standards are developed by the International Telecommunications Union Telecommunications Standardization Sector (ITU-TS), formerly known as CCITT. Different countries make their own refinements of the ITU standards as necessary. The discussion here is limited primarily to North American networks. The American National Standards Institute (ANSI) and Bellcore further refine the ITU standards for North American and Regional Bell Operating Companies (RBOCs) respectively.

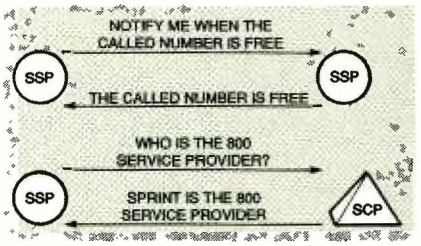

FIG. 2—CLASS (Custom Local Area Signaling Services) and Enhanced 800 services using TCAP (Transactions Capabilities Part) queries.

Virtually anyone in the communications field today will recognize the Open Systems Interconnection (OSI) model. The OSI stack was developed by the

Continued on page 54

www.americanradiohistory.com

SIGNALLING SYSTEM 7

continued from page 30

International Standards Organization (ISO) and contains seven layers identifying communications functions between two nodes such as the physical medium used for the connection, the error correction method, addressing scheme and so on. SS7 is also a protocol and is based on the OSI protocol stack.

The Protocol

The SS7 protocol (refer to Fig. 3) is composed of:

- Message-transfer part
- Signaling connection control part
- ISDN user part
- Transaction capability application part

The MTP (message-transfer part) provides the basic transport system for all SS7 messages. It is somewhat like a delivery truck. It is responsible for getting information from one network node to another in a reliable fashion. It makes up the first three levels of the protocol stack; the physical, link and network layers.

Layer 1, the physical level, specifies the actual medium used for transmission. It uses a four-wire connection and typically a bit-rate transfer of 64 kilobits per second (kb/s) or 56 kb/s. V.35 connections may also be used with incremental transmission rates up to 64 kb/s.

Layer 2, the link level, provides a number of functions to ensure that there is a good connection between two nodes for communicating. Error detection, error correction, signaling unit alignment and signaling link alignment are all part of the link layer's responsibility. It is at this layer that the actual signaling unit is formed. Signaling units are simply SS7's version of packets. Signaling units are transmitted across the signaling link continuously whether there is any information to transmit or not. When there is actually a message to be sent, it is sent in an MSU (message signaling unit). During periods when there is no information to send, FISUs (fill-in signaling units) are sent. This continuous stream of packets ensures that link problems are detected immediately. There is a third type of signaling unit, an LSSU (link-status signaling unit) which is used to convey changes in the status of the link between the two ends.

Layer 3, the network layer, has two basic responsibilities: address routing and network management. The first of these involves looking at the address of each packet to determine its destination. This also requires that alternate routing and recovery procedures are implemented when a network failure occurs.

The SCCP (signaling-connection control part), which is part of Layer 4, provides additional routing and network management functions to the MTP. It allows applications to talk to each other at different nodes, and it provides network management capabilities at the application level. For example, an application may want to reroute a message in the event of an application failure. You'll note from the SS7 protocol model (Fig. 3) that there is a connection between the ISUP and SCCP layers. SCCP contains connection-oriented procedures that may be used by ISUP; however ISUP doesn't use them today. It can communicate directly with MTP which suffices for current ISUP needs. New services may however make use of the SCCP connection-oriented capabilities.

The ISUP (ISDN user part) of Layer 4 provides connection-oriented signaling between nodes. This type of signaling relates to setting up, taking down and monitoring the connection of the actual voice path between offices. ISUP is what provides the capability for phone calls to be completed. It also provides services such as Caller ID. The name ISDN User Part can be a bit misleading, however, because you don't need to have ISDN to use this capability. It was however designed with ISDN capabilities in mind.

TCAP (transaction capabilities application part), also part of Layer 4, allows connectionless communications between two applications using generic language. It provide query and response capabilities allowing nodes to request and respond to network and servic information regardless c whether there is an actual ca established between office This opens up an entire world of database interaction allowing centralized network intelligence in handling calls.

Now that you have an idea of how the protocol works, let's move to a network viewpoint. As mentioned earlier, SS7 is essentially overlaid on the existing telephony network. This introduces some new network elements as well as giving additional capabilities to previously existing ones. The network is

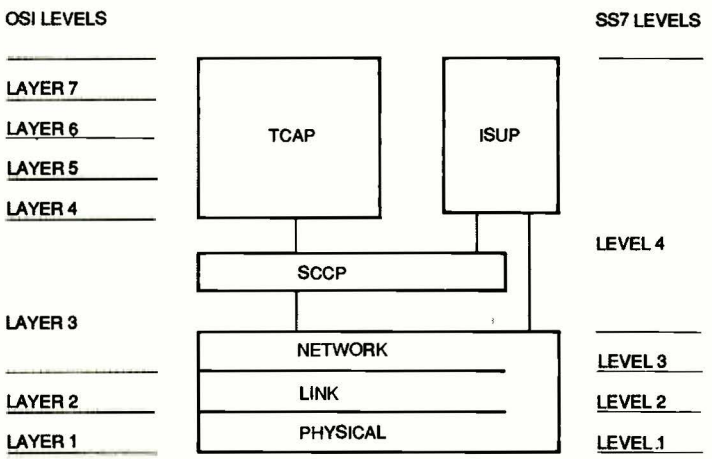

FIG. 3—OPEN SYSTEMS INTERCONNECTION (OSI) and Signaling System 7 (SS7) protocol models.

www.americanradiohistory.com

made up of a number of nodes called signaling points. Figure 4 shows a network example consisting of connected nodes.

The SSP (service-switching point) is the telephone office with SS7 capabilities. It can originate and terminate messages but cannot transfer them. The STP (signaling-transfer point) takes care of the transfer part. It is the message-switching hub of the network, essentially a big packet switch. Many of the routing decisions are made at the STP. Without this node, every SSP would need to have a connection to every other SSP it was required to send messages to. This would quickly grow into a complicated scheme. STP's are usually deployed in mated pairs to provide redundancy.

The SCP (service-control point) provides database services. Telephone offices can send queries to the database requesting information regarding 800 numbers, Private Virtual Network numbers and calling-card numbers, to name a few.

Network routing

We have seen that the physical connection between offices that provides the signaling communications is called a signaling link. This link is actually a part of a linkset. A linkset is simply a set of signaling links connecting two offices. ANSI specifies that a linkset may contain up to 16 links. Many offices might be able to handle all of their traffic on a single link per linkset. However, the desire for additional traffic capacity or just alternate facilities in the case of a facility failure often merits additional links. There can only be one linkset defined between two offices. While links define physical connections between offices, a *route* describes the path between a node and a destination.

A route may consist of multiple linksets. There may be several routes from one node to another. Each route follows one or more linksets to its destination. Just as there may be several links in a linkset, a routeset is a set of routes which describes alternate paths from a node to a destination. When a node needs to send a message to another node, it chooses a routeset which is associated with a destination, then chooses a route within the routeset (remember that a route really just describes a linkset), then chooses a link within the linkset.

That brings us to the next topic of routing: how to determine which node to send a message to. Every office is assigned a point code. This is the address of the office, simply a number to uniquely identify it. Point codes vary in format depending on the country and the standards they use. The ANSI standards used by North America designate a 9-digit point code to identify each node in the network. Each message contains both a destination point code to identify the office to send the message to and an origination point code to identify the office sending the message. Within each office, translations are done to map this address to a routeset for which outgoing messages are to be sent. This means that each node must designate routesets for each point code it wishes to directly send messages to.

The decisions about how routing will be done can vary from company to company and are made by administrators of the network. This type of routing based on the point codes is done at the network level of the MTP and its primary responsibility is getting messages from one node to another.

The next level of routing to consider is routing to an application, or in SS7 terms, a subsystem. Subsystem routing is also based on a number designated for a specific application. This number must be agreed on by different companies so that a subsystem number identifying a particular subsystem can be interpreted correctly. These are usually not defined in the more general standards, but are usually defined by those involved in network administration. For instance, Bellcore, the research and development organization for the regional Bell operating companies has defined a number of subsystems for their clients in the US. One example is Custom Local-Area Signaling Services (CLASS), which has been defined as subsystem 251. Therefore, two offices sending CLASS related messages would designate a subsystem of 251 in the message. Subsystem routing is the responsibility of the SCCP level of the protocol. At the beginning, we determined that the digits of the telephone number played a major part in determining how your call is routed through the network.

One of the popular buzzwords in SS7 terminology is something called *global title translations*. A global title is simply a set of digits. These may be digits dialed by a subscriber or provided by an application by some means. Global title translations is the process of mapping those digits to an SS7 address, namely a point code and a subsystem. We've determined that a point code can route a message to an

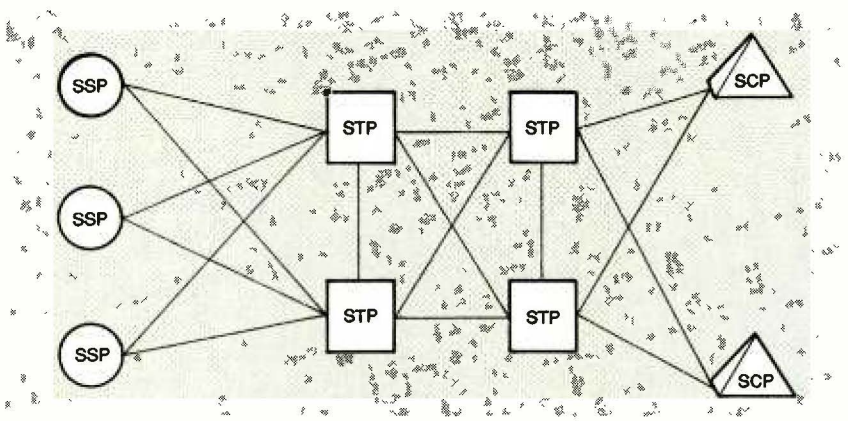

FIG. 4—AN SS7 SIMPLIFIED NETWORK showing Service Switching Points (SSP) interconnected to Service Control Point (SCP) via a network of Service Switching Points (STP). SSP, SCP and STP are nodes providing specialized services.

www.americanradiohistory.com

office and a subsystem number can route to an application. Once these two pieces of information are determined, we have the means to get a message from our application to an application somewhere else in the network. Traditional routing in the telephony network is based on digits. You realize that fact every time you pick up the phone. However, the SS7 network routes its messages based on point code and subsystem. Therefore global title translations are needed, which is also a function of the SCCP layer of the protocol.

Let's summarize how messages are routed across the SS7 network. When a call begins its routing process, the dialed digits are examined. For connection-oriented calls using the ISUP layer of the protocol, the digits are mapped internally to the appropriate point code by the office sending the message to the next node. The ISUP message also contains a circuit-identification code to identify which trunk the message relates to. This is necessary because it will be traveling on a different facility from the actual voice or data call. If level 2 has determined that both ends of the signaling link are at a suitable level of service, level 3, the network level routes the message to the next office based on the point code.

Now, assume that you're sending a TCAP message to a database to determine information related to an 800 number. (Refer to Fig. 5.) The point code to send the message to would still have to be determined, but a subsystem number would be needed also. The protocol model shows that a TCAP message must ride on top of the services of SCCP. Since TCAP is a connectionless message that's normally related to an application, the subsystem routing services of SCCP are needed. This is where global title translations comes into play. From the SSP, the message might be sent to the STP to let it perform the translation on the 800 number and determine how to route it to the database. In fact, this is what's normally done.

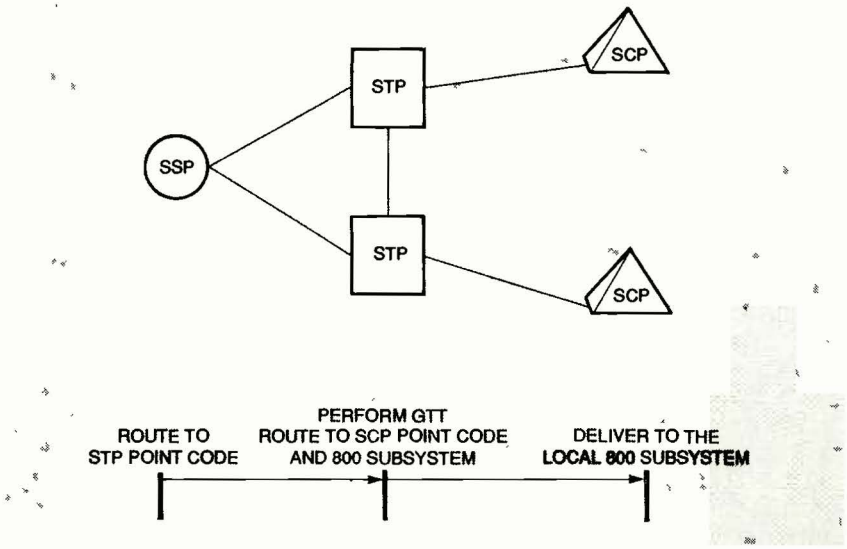

FIG. 5—AN EXAMPLE OF SS7 routing to determine information related to an 800 number. From the SSP a message goes to the STP and it performs the translation on the 800 number and determines how to route it to the correct 800 database.

It is not necessary for all of the offices to have knowledge of the database locations. This can be taken care of at a centralized point, the STP. Routing might occur through multiple STPs before reaching the SCP, but by the time it arrives, the final point code and subsystem have been determined so that the 800 application software at the appropriate database can handle the message.

The self-healing network

The headlines citing major SS7 outages give insight into the importance of the signaling network. If an office uses SS7 signaling, its loss means that the office can't communicate with the rest of the world. It becomes isolated. The network and protocol design take this into account, providing alternate routing, compulsive restoration where possible, and internodal communications to coordinate activities concerning degradation or loss of service. The network management implemented by the MTP can be divided into three categories: signaling-link management, signaling-route management, and signaling-traffic management.

Together, these management procedures attempt to maintain service by re-routing or controlling traffic when there is congestion or a failure in the network. Built-in recovery procedures attempt to restore network components to service if possible.

Signaling-link management is responsible for maintaining the path between nodes. If excessive errors are detected by the link layer, the link may be deactivated. Signaling link management will attempt to restore the link through a process known as signaling link alignment. This involves an exchange of signaling units (LSSUs) to bring the link back to the proper state. Each end of the link uses a signaling-unit error-rate monitor to monitor the number of errors at the link level and determine the stability of the link. When signaling-link management has determined that the link is suitable for use, it will report it to level 3 as being available.

Signaling-route management maintains and distributes information between nodes on the availability of signaling routes. Much like a traffic reporter, it sends out messages about the loss or degradation of routes causing other nodes to choose alternate routing or take appropriate actions.

In Fig. 6, for example, assume that the link between SSP A and STP 1 failed. The STP would

www.americanradiohistory.com

send a transfer-restricted (TFR) message to the other SSPs informing them that it has limited routing capabilities to access node A. The TFR message would contain the point code identifying node A as the subject of the message. As long as the other nodes are able to route messages by another route, they will not try to access node A through this STP. This helps to minimize the traffic between the two STPs unless it is absolutely necessary, since STP 1 would have to route any messages it received destined for A through STP 2. The other network nodes can still route through STP 2 with no problem.

Since STP 2 will not be able to send messages to SSP A via STP 1 at all, STP 1 sends a transfer-prohibited (TFP) message to STP 2. This message contains the point code for SSP A marking its route as unavailable for messages coming from STP 2 in this direction. As you can see, the only way STP 1 can get a message to SSP A would be to route it through STP 2. It would have to send the message right back, causing double traffic over the link joining the two STP's. The TFP will prevent that situation.

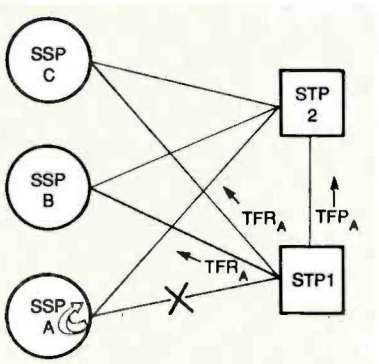

FIG. 6—NETWORK MANAGEMENT automatically re-routes messages in the event of failures.

When the route between STP 1 and SSP A is restored, STP 1 will send out transfer-allowed (TFA) messages to its adjacent nodes, informing them that routing is again available to SSP A. There are additional messages that are used to accomplish all the tasks that need to be handled by routeset management but this scenario gives you an idea of how nodes communicate the availability of routes between each other.

GLOSSARY OF TELEPHONE NETWORK TERMS

AIN—Advanced Intelligent Network. A network concept in which services are created and managed in a centralized location. This moves the service intelligence from the telephone office to a service control point.

ANSI—American National Standards Institute. Refines the Global SS7 standards specified by the ITU-TS for North American and regional Bell operating companies.

Associated mode—Signaling mode in which a node is directly connected to the destination node by a linkset.

CLASS—Custom Local Area Signaling Services. A set of services usually targeted for residential and small business which provides the equivalent of many business features such as caller identification and automatic recall.

Connection-oriented signaling—Signaling used to set up, monitor and take down calls or pass information related to a call connection.

Connectionless signaling—Signaling used to transfer information not associated to a particular connection. Often referred to as a Query/Response method.

FISU—Fill-in signaling units. An SS7 packet sent when there are no MSUs to be sent. Since SS7 links transmit a continuous stream of packets, these are used as filler when there are no messages which need to be sent.

Global title translations—The process of converting digits to an SS7 address. SS7 uses point codes and subsystems to deliver messages.

ISDN—Integrated Services Digital Network. A network concept which provides multiple integrated services from a single point of access. ISDN provides access to voice, circuit-switched data and packet-switched data as well as enhanced call control signaling from the end user to the telephone office.

ISUP—ISDN user part. Part of the SS7 protocol which provides connection-oriented signaling used for setting up, monitoring and taking down trunks.

ITU-TS—International Telecommunications Union–Telecomunications Standardization (Sector). Organization that determines Global SS7 Standards.

Link—A communication channel between two adjacent signaling points which provides a path for messages to travel.

Linkset—A set of links between two adjacent signaling points

LSSU—Link-status signaling unit. An SS7 packet used to convey changes in the link state between nodes.

MSU—Message-signaling unit. An SS7 packet used to send information across the network.

MTP—Message-transfer part. Levels one through three of the SS7 protocol. MTP provides reliable transfer of signaling units between network nodes. Its responsibilities include point code routing and network management.

NSP—Network-service part. Refers to the combined services of MTP and SCCP. Together, these provide end-to-end application routing.

OSI—Open System Interconnection. The telephone hook-up system commonly used throughout the world.

Point code—An address for an SS7 network node.

Quasi-associated mode— Signaling mode in which a message must travel over two or more linksets to reach its destination. It is not directly connected to the destination point.

Route—A path from a signaling point to a destination.

Routeset—A collection of routes used to access a destination.

SCCP—Signaling-connection control part. Part of the SS7 protocol which provides additional routing capabilities to the MTP, including subsystem routing and global title translations.

SCP—Service control point. A database used to access information about calls such as routing, billing and the selection of the service provider. The SCP provides a centralized form of intelligence for handling calls.

SP—A signaling point that can originate and terminate SS7 messages but does not have TCAP capability. The term signaling point is sometimes used to refer to any network node with signaling capability; however this should not be confused with the specific "Signaling Point" node type.

SSP—Service-switching point. A node that can originate and terminate messages but does not have the capability to transfer them. It also has the ability to send TCAP messages.

SS7—Signaling System 7. A system that specifies the signaling protocol for the telephone network.

STP—Signaling-transfer part. A node used to transfer messages between other switching nodes. Acts as a message switching center.

subsystem—An application at a node which uses the routing capabilities of SCCP.

TCAP—Transaction Capabilities Part. Part of the SS7 protocol which provides a generic format for transferring application-related information.

Trunk—Facility which carries voice or data traffic between two telephone offices.

www.americanradiohistory.com

The third area of network management is signaling-traffic management, which is responsible for routing the traffic in the network as the availability of routes change. Let's take our previous example and look at how traffic management handles this situation. At SSP A, all traffic destined for STP 1 must be stopped and re-routed to STP 2. Link-layer procedures exist to attempt to account for all messages which might have been in transit between the nodes when the failure occurred to ensure that messages are not lost. This communication is done using the route through STP 2. This coordination between the two nodes terminating the faulty route is called a changeover and is one example of how traffic management works in the SS7 network. Traffic which was destined for the linkset to STP 1 will now be changed over to the linkset for STP 2.

Again, there are a number of such procedures that make up signaling-traffic management. Congestion procedures were not even mentioned. But network management is a big subject—it's hard to predict the future, especially with the rate of change that's taking place in communications today. However, as you read, a great deal of development is being done in the area of centralized services such as the Advanced Intelligent Network (AIN). These services rely heavily upon the SS7 protocol to communicate.

We have only scratched the surface of all the inner workings of the SS7 network, but I hope it's enough to spark your interest in some further reading. I spoke with Travis Russell, the author of the only book I've seen to date that's totally dedicated to the subject and asked, "Why did you decide to write the book?". He replied, "Because there simply wasn't anything out there that was comprehensive." Russell writes from a wealth of practical experience and discusses a number of the network services which use the SS7 protocol. The book is titled "Signaling System 7", McGraw-Hill publisher. Ω

It started in America!

The creators are the masters in manufacturing the finest video products...

For the clearest pictures you ever record!

You probably don't associate VCR's with American technology. Fact is, video recording has its origins in America and it was 3M that brought video recording out of the lab and into your living room. Today, 3M video tape is the choice of all the major networks. No other tape company has ever won an Oscar or an Emmy. 3M Black Watch tape follows in this tradition—service and quality go hand in hand. Here are three Black Watch products you should be using at home!

Clean up! With constant playing and using of degrading dry or wet cleaners, the output of your video tapes has slowly diminished to an unacceptable level and the VCR plays as if it has a head cold! The culprit is most likely clogged and dirty video and/or audio heads. The 3M Black Watch™ Head Cleaner Videocassette uses a patented magnetic tape-based cleaning formation to remove head clogging debris. No foreign substances such as cloth, plastics or messy liquids and no harsh abrasive materials are present. The cleaner's usable life is 400 cleanings or more!

It's easy to use. Place the 3M Black Watch™Head Cleaner Videocassette in the VCR and press the Play button. A pre-recorded message will appear clearly on your screen and an audible tone is heard, telling you that the cleaning process is now completed. No guess work; you never over clean! Priced at $19.95.

For the VCR! Once your VCR's record and playback heads are cured, and the unit plays like new, consider using the finest videocassette you can buy—the 3M Black Watch™ T120 Hi Pro VHS 4410 Videocassette. The 4410 is the highest performing videocassette available today for use with all standard format VHS recording hardware!

Here's what you hear and see....A sharp, clear picture—brightest ever colors—freedom from streaks, flashes and snow—outstanding high-fidelity audio reproduction—optimum camcorder performance—maintains recording integrity. 3M Black Watch™ video tape is 100% laser inspected to guarantee surface smoothness and drop-out free performance. Priced at $8.00

You saw it here first! 3M Black Watch™ 0900 8mm video tape cassette loaded into your Hi Band camcorder delivers the finest picture and sound possible in the 8mm format. Extremely fine particles of pure iron alloyed with nickel and cobalt deliver a video performance exceeding 400 lines of horizontal resolution. You get the advantage of an exceptional video image with superior audio reproduction. This means your Hi 8 format camcorder will produce the best video and audio definition possible. With the 3M Black Watch™ 8mm cassette, the recording capability and performance of your camcorder will be significantly enhanced. Priced at $14.95.

Claggk Inc. — 3M VHS Special Offer
P.O. Box 4099,
Farmingdale,
New York 11735

Yes, I like your offer and here is my order for 3M Black Watch™ products!

___ 3M Black Watch™ 0900 Hi Band-120 8mm Cassette **($14.95 each)** $_____

___ 3M Black Watch™ T120 Hi Pro VHS 4410 Videocassette **($8.00 each)** $_____

___ 3M Black Watch™ Head Cleaner Videocassette **($19.95 each)** $_____

Shipping and handling per order **$4.00**

Total Amount in U.S. Funds only $_____

New York residents add local sales tax. Canadians **add $6.00** per order. No foreign orders. Do not send cash.

Bill my ☐ VISA ☐ MasterCard
Card No._____
Expire Date ___/___/___
Signature _____
Name (Please print) _____
Address _____
City_____State_____ZIP ____

www.americanradiohistory.com